Flocculation: What the floc is that all about?

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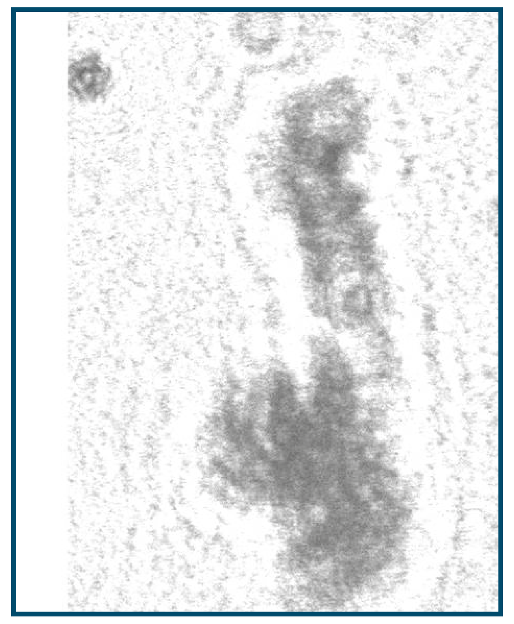
What is it?

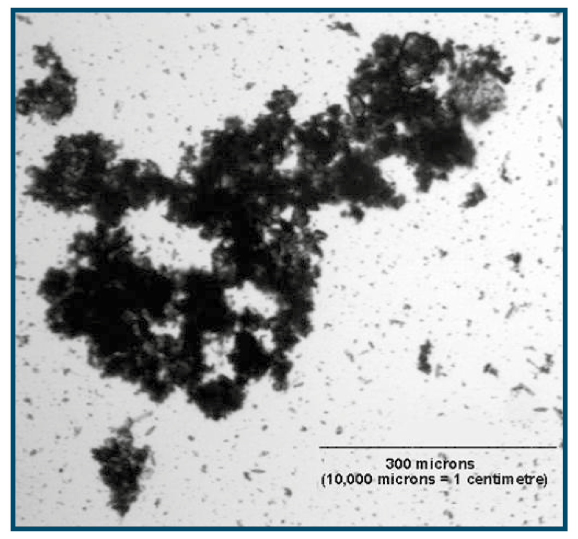
A floc is [OED] “a loosely clumped mass of fine particles.”

Or…an aggregate of particles with a complex random structure and low average density, resulting from flocculation within an aquatic medium.

Or…naturally cohesive and adhesive collections of minerals, and usually but not always, organic matter in a loosely bonded, porous state.

Most material in estuaries and coastal seas exists in the form of flocs.





Are there different types?

Every floc is different - like underwater snowflakes. They vary from small, quasi-spherical, compact structures to large, complex, multi-cored particles connected by super fine, almost invisible threads. Some flocs are highly organic, whilst other are almost entirely mineralic in composition. Floc structure, as well as the mineralic and organic composition can all vary greatly.

Flocs are loosely classified as belonging to one of three types:

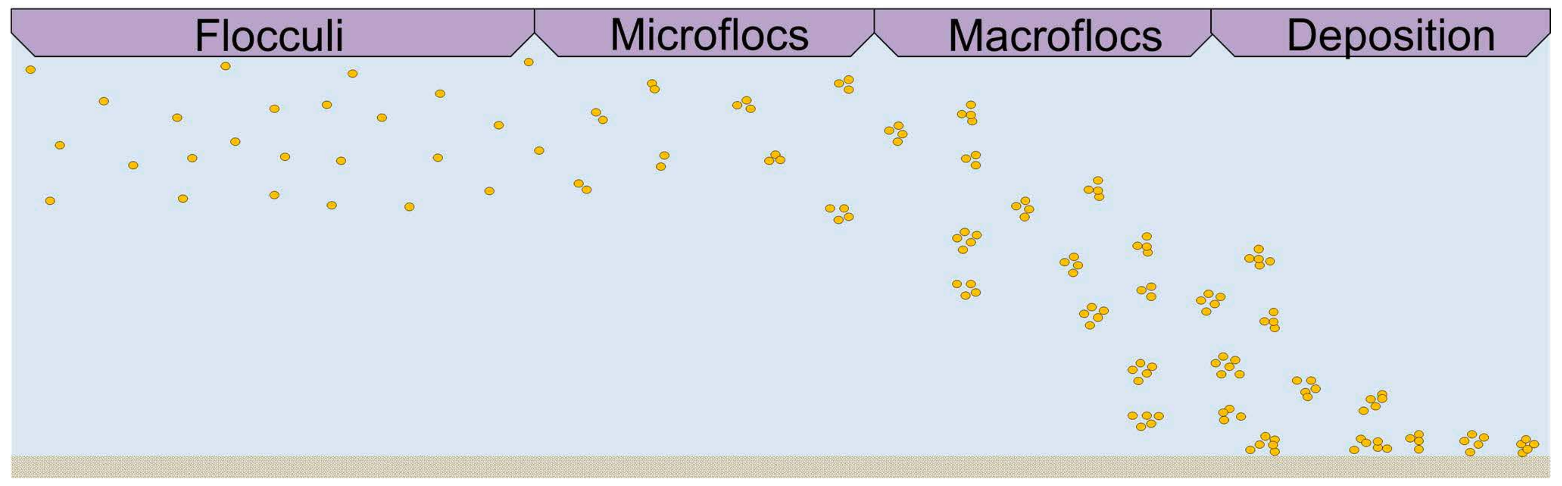
Flocculi: The “building blocs” of flocs. Small collections of clay platelets with little organic material up to a few μm in size

Microflocs: Strong, dense, shear-resistant collections of flocculi, mineral particles & organic matter. Usually up to ~160 μm in size

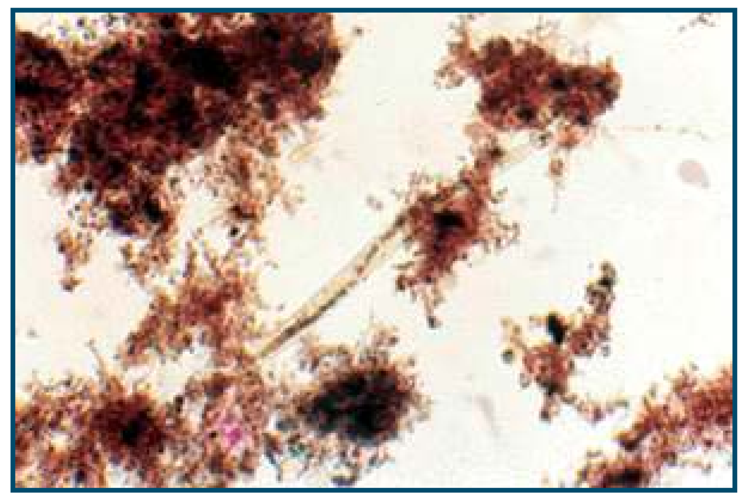
Macroflocs: Large, low-density, fragile collections of microflocs and organic material. arbitrarily set at ~160 μm by Manning, Dyer, Winterwerp and others.

In reality this change is gradual, taking place over a range of sizes as flocs transition from microfloc to macrofloc characteristics.

Floc growth is not a one-way transition: macroflocs are broken down under conditions of high turbulence into their constituent microflocs, and, under very high turbulence, microflocs may be broken down into flocculi.



How does it work?

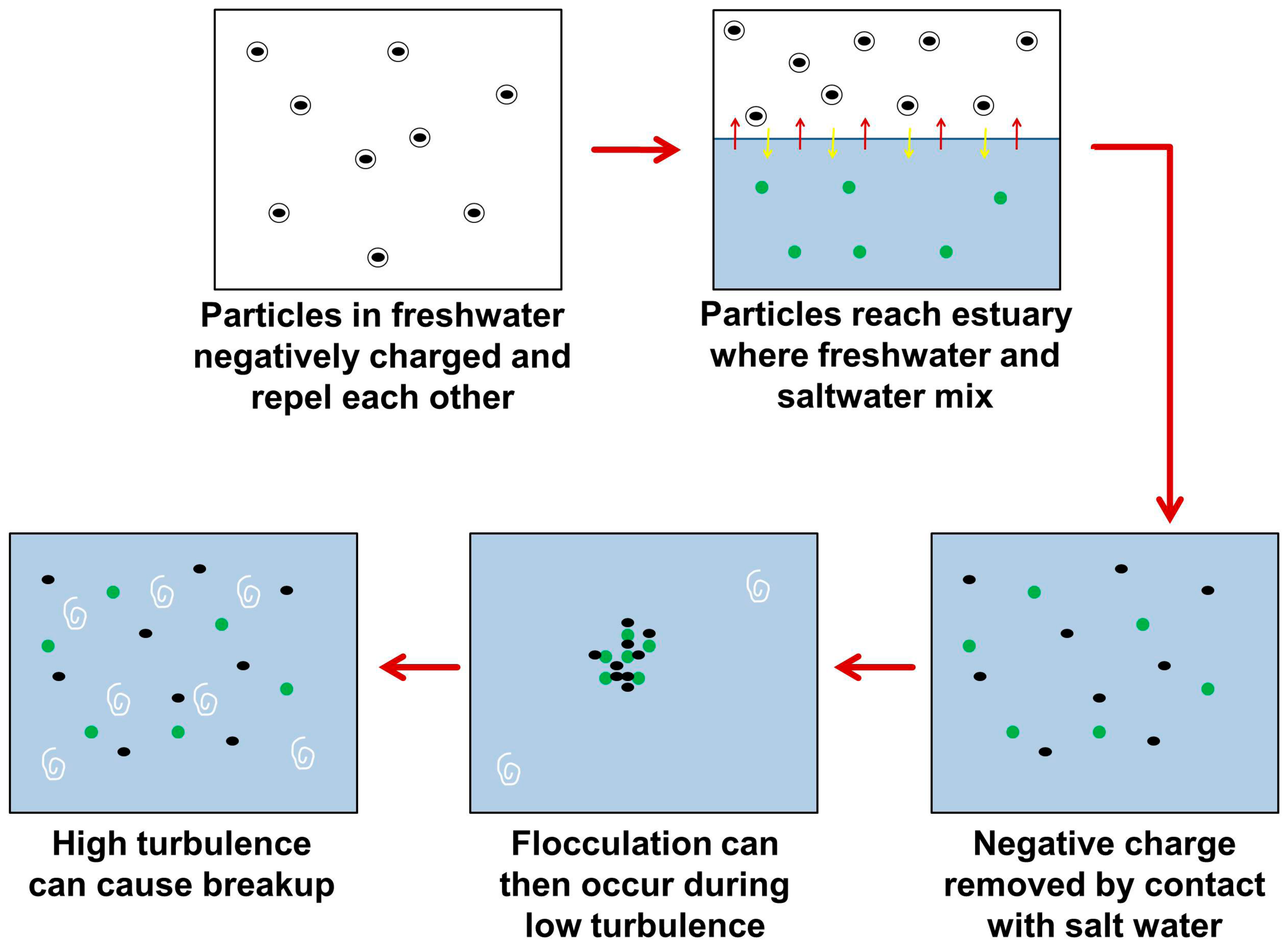


Flocculation is governed by three major processes: those that bring particles together, those that keep them together, and those that break them apart

Bring together: Low levels of turbulence, organisms that package particles into faeces or attach to mucus

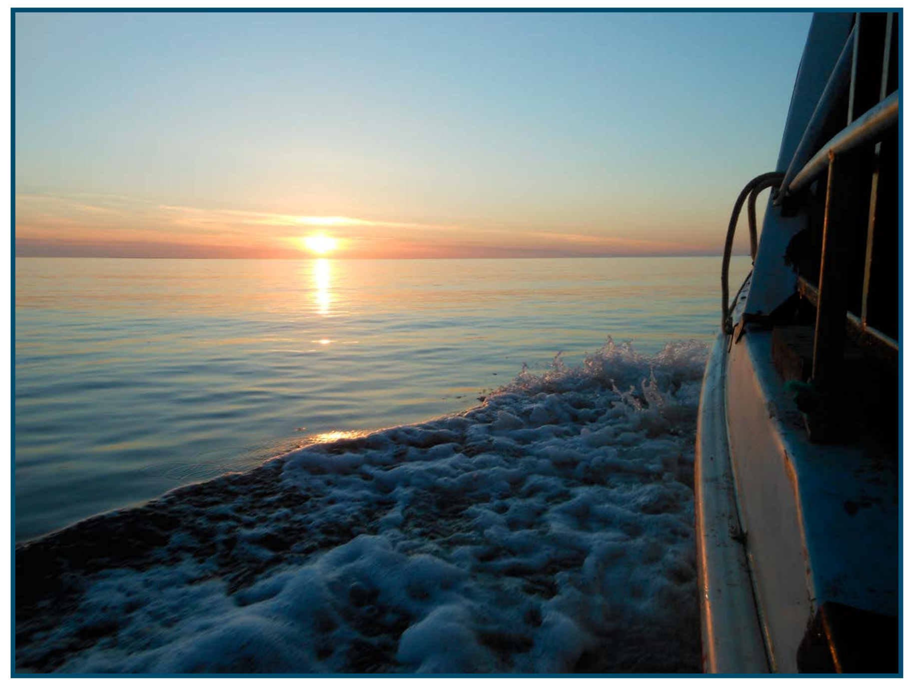
Keep together: Particle-Particle Forces, Sticky organic matter

Break apart: High levels of turbulence, organic matter breakdown

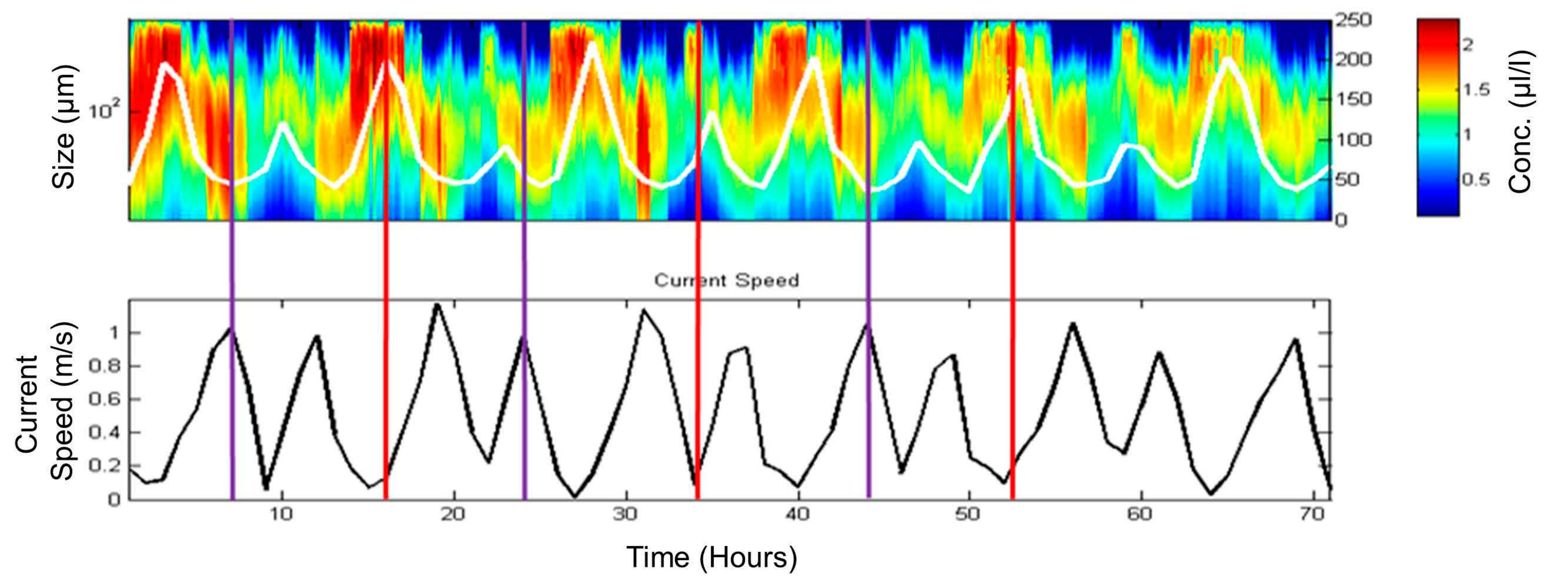


In general, the threshold which governs the size that flocs are able to reach is the Kolmogorov microscale – the size of the smallest turbulent eddies within a system.

Flocs will continue to grow, under conditions conducive to floc growth, until they approach this size. Weaker flocs will stop growing well before they reach this size, while recent research has shown that strong, highly organic flocs are able to grow to sizes that exceed the Kolmogorov microscale.



What does it look like?



The data above was recorded by a Sequoia Scientific LISST-100X Type C in the Dee Estuary during February-March 2009, with current speeds in the bottom panel provided by an ADCP.

In the top panel, time is shown on the X Axis, particle size on the Y Axis, and colour represents particle concentration.

High concentrations of small particles occur during peak current speeds on both the flood and ebb tides, indicating resuspension and floc breakup.

By contrast, high concentrations of large particles occur during high & low water as flocculation occurs during low current speed conditions.

Great flocculation occurs during low water for several reasons:

> A horizontal concentration gradient was present (not shown) which brought abundant small particles down the estuary during the late ebb tide

> Tidal asymmetry resulted in low water being on average 2.2 x longer than high water, providing more time for flocculation to occur

> The dilution effect, which makes particle collisions more likely during low water

Impacts of flocculation

As flocs grow, their settling velocities increase, despite their density decreasing.

The increased settling velocity improves water clarity as particles settle out faster from the water column.

In shallow water, as flocs have higher settling velocities than their individual particles, they settle faster and are therefore transported shorter distances, resulting in a decrease in overall sediment transport.

In deep water, increased settling velocities mean that particles sink to greater depths before they are remineralised, providing a vital food source to the deep ocean in the form of marine snow.

The inclusion of flocculation in cohesive sediment transport models is of paramount importance due to the wide occurrence of flocculation in the coastal ocean. Cohesive sediment transport models that do not include flocculation processes may be highly inaccurate.